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STEM EDUCATION: INTRODUCTION OF QUANTITATIVE MATH AND SCIENCE CONTENT INTO ELEMENTARY EDUCATION

Stem Enrichment Effort in Title One Elementary and Middle Schools In Bay County, Florida

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Final Report

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PREFACE

This report describes activities executed by the STEM Center, Florida State University, Panama City branch campus, its contractors and a group of partially compensated volunteer teachers in the Bay County public school system (BCSS) during the 2011–2012 and 2012–2103 school years. The project officer was Dr Joe Wander, AFRL/RXQ. Funding was provided by the Air Force Science, Technology, Engineering & Mathematics (STEM) Outreach Coordination Office (AFSOCO) through grant FA4819-11-1-5218, awarded in connection with an educational partnership agreement between AFRL/RXQ and BCSS.

1. SUMMARY

Ignorance about and even phobias against science abound in the general US population, and the Department of Defense is investing substantial sums of money to rekindle student interest in careers in technical areas (science, engineering, technology and mathematics—STEM). Several factors contribute to each of these situations but a prominent factor they share is the absence of quantitative content in elementary school classrooms—the educational window in which many lifelong attitudes are formed.

Seeking to “measure” this problem and to evaluate the effect of systematic intervention in the form of teacher enrichment, the Air Force’s STEM program at Tyndall Air Force Base (AFB) undertook a program with the Northwest Florida Regional STEM Center, located within the Panama City branch campus of Florida State University (FSU-PC), to track and compare scores on standardized tests (administered at intervals to evaluate student progress) in two groups of grade 4, 5, 6 and 7 classrooms that included a number of Title 1 students—a set of controls who followed the standard curriculum and a test group, whose teachers 1) before and during the 2011–2012 school term (SY 2011–2012) participated in two weekends of hands-on laboratory experiences guided by a subject-matter expert (SME) who also developed lesson plans to which the lab experience was relevant and 2) received an aquarium, a digital microscope, minor equipment items and supplies, and a kick net with which each collected coastal marine biota to populate the aquaria.

Several uncontrolled factors complicated the execution of the project. Turnover of both students and teachers in Title 1 classrooms was high, and both eroded the *n* for the data set. The initial contracting strategy was processed at length and eventually rejected, which delayed the start of preparations and dissipated the initial enthusiasm of the participating teachers. The SME commuted from the upper Midwest for the weekend sessions and was not available on call; only part of that gap was covered by middle- and high-school-science master teachers—direct contact time was insufficient. And strains deriving from a combination of factors eventually led to departure of the SME and master teachers from the end of the second training session to the end of SY 2011–2012.

A new master teacher was recruited during SY 2012–2013 but the combination of loss of corporate memory and talent with the departure of many critical personnel and students made it impractical to attempt to continue the original enrichment exercise, so the experiment was not continued during the new term as a measurement of residual effect on the participating teachers’ new classes and students advancing from the participating classrooms.

The missteps during startup were one-time events at the site but are a risk to recur at new locations, and should be identified as lessons learned and not to be repeated; however, the intrinsic instability of Title 1 students and classrooms is relatively constant and will degrade the efficiency of local efforts to effect such enrichment unless and until it is implemented nationally. However, that education in Title 1 schools is intrinsically limited by extracurricular distractions limits the efficiency of such a STEM promotion effort and raises a question about the purpose of that effort. Whereas the social value to Title 1 programs initially appears obvious, the return in the form of increasing the pool of students opting for STEM careers might be greater if the investment were directed at a more-secure economic class.

2. INTRODUCTION

The Department of Defense (DoD) and a variety of other organizations are investing in a number of innovative programs aimed at drawing a larger number of young US citizens into careers in various fields of engineering, and into supporting areas of science and mathematics, under a broad umbrella of science, technology, engineering and mathematics (STEM) activities. The most dramatic and visible STEM activities, e.g., Project Lead the Way (PLTW), have been directed primarily at high-school and secondarily at middle-school age groups, presumably in proportion to their capacity to conduct elaborate projects. However, preferences of subjects and most personal attitudes are already well established by the end of middle school, and math and science phobias are firmly engrained. A consequence of this is widespread ignorance and irrational and inappropriate fear of science and technology—a failing of the educational system that leaves the public vulnerable to exploitation by intimidation and disinformation disseminated through both traditional and social media.

When this project was undertaken Bay County (Florida) was the site of several active, engineering-oriented STEM projects aimed primarily at students in the higher grades, and science scores by the county's public school students in elementary grades have had a long history of ranking close to the national average at the end of grade 3 (science is introduced in grade 4), falling drastically at the end of grades 4 and 5, and recovering only gradually in later grades. The curriculum that trains primary and middle school teachers in Florida (and generally throughout the country) emphasizes method over content, and math and science courses are generally only electives in a crowded environment of coursework biased toward development of language skills—i.e., the group that teaches elementary school grades appears to functionally select for math and science phobics.

Teacher enrichment programs are typically studied through measures of progress of the teachers, whereas a metric of at least equal importance—particularly to a STEM project—would be the students' performance and career decisions. Bay County's problem with science test scores has been recognized for decades and has been attacked with earlier local projects, of which some temporarily showed anecdotal positive results from enrichment exercises, but the successes and lessons learned using this potentially valuable metric were not documented and have since been lost. This project is an effort to implement a systematic enrichment of science content by expert development and presentation of classroom and field exercises to a subset of the county's grade and early middle school teachers in vertical columns of schools feeding two of the county high schools, and to track and compare average scores of students in participating classrooms to those of students in nonparticipating classrooms for several years. When sufficient data are in hand the eventual goal is to expand the science content and preparation in the elementary education training curriculum to institutionalize the advances realized in the participating classrooms. More-useful data are expected to evolve in subsequent years, when the dimensions of the ripples several years downstream have been mapped and when the participating teachers have assimilated experience in applying their new skills in the classroom.

It is encouraging to note that since the inception of this project PLTW has announced that they will expand their programs into the elementary schools.

3. METHODS, ASSUMPTIONS, AND PROCEDURES

The assumptions on which this project were based are few and simple: that any classroom of 25 randomly assigned students within a grade in a single community's school system is a large enough group to be considered representative of the population served by that school, and that a comparison of trends in scores on standardized achievement tests by participating and nonparticipating (control) classes in the same school will provide a quantifiable metric for each grade involved. The weakest assumption—imposed by the limited scale of the exercise—is that differences in the innate abilities of the teachers will not be a confounding factor in the comparisons.

3.1. Project Organization

Bay County's public school system (BCSS) includes a small cadre of "master teachers": science teachers in the higher grades who invest time and effort, first to earn the master teacher designation and then to share their experience with other teachers in the school system as coaches, mentors, consultants—whatever is appropriate to the individual interaction. One master science teacher at each of two BCSS urban high schools volunteered to be at the top of a vertically aligned column of feeder schools and mentor a pair of teachers in grades 4, 5, 6 and 7 of lower schools feeding students to their respective high schools. Both vertical columns included schools with significant populations of Title 1 students. During the 2011–2012 school term each master teacher was assigned two participants in each of the four lower grades; the following year a single (new) master teacher was emplaced.

3.2. Planning and Contracting

During the course of the planning and contracting phases of this project, Florida State University, Panama City Campus (FSU-PC), achieved designation as the area center for STEM activities. The evolution of the project began with identification of Prof (Retired) Wynne Lewis, a microbial ecologist and respected educational consultant, as a subject matter expert (SME) to develop and deliver content and to provide local support, primarily to ensure efficient transmission to the master teachers, who carried day-to-day responsibility for coaching/mentoring/guiding the teachers in their respective vertical queues.

The initial contracting strategy was to make separate awards to Prof Lewis and to FSU-PC, to generate and deliver content and to provide supplies, facilities and modest stipends to participating teachers, respectively. Data collection, analysis and technical reporting were to have been a shared task overseen by Prof Lewis. After numerous documents had been generated and messages exchanged with the contracting office it was determined that a sole-source award to FSUPC would be possible but that an award to an educational consultant's would require a full and open competition, which was impractical—enough time had been invested at the time this decision came down that a competitive process would have delayed the project start date beyond the start of the 2011–2012 school year. To keep to a workable project timeline a surrogate contracting officer's technical representative (COTR) was appointed and the strategy amended to a single award to FSU-PC, who subcontracted Prof Lewis as a part-time employee. Time pressure forced us to this expedient, which included a change that proved to have profound operational consequences—shifting control of the project from the SME to the FSU-PC program manager (PM).

Concurrent with the year of contracting vicissitudes, a series of organizational meetings of master teachers, the PM and functional COTR were held, generally in FSU-PC's facility. These included inputs from Prof Lewis, either electronically or in person. The recurring revisions that eventually accomplished a legally sufficient correction of the poorly conceived contracting process delayed the availability of funds for the teachers to "make things real," with the unfortunate consequence of losing much of the initial enthusiasm and momentum. A key step in the eventual awarding of the grant to FSUPC was establishment of Educational Partnership Agreements between the local Air Force organization (AFRL/RXQ) and FSU-PC and the Bay County school system—which, in hindsight, should have been the first step. A grant was finally awarded to FSU-PC in August 2011, at the eleventh hour for implementation for SY 2011–2012.

3.3. Implementation

3.3.1. 2011–2012 School Year

Bay County is a coastal area rich with extensive estuarine environments. To capitalize on this asset—both scientific and contextual—each participating classroom was given an aquarium and a digital microscope to provide access to local fauna as relevant objects for long-term study. Supplies for the year were provided as well, and will continue to be so for the anticipated duration of this multi-year exercise. (Appendix A is a complete list of equipment and supplies provided to each teacher.) These were installed in the classrooms and a weekend training session in mid-September was conducted by Prof Lewis, both for and with the help of the master teachers, and attended by a bit more than half of the participating teachers. This exercise was conducted to familiarize the teachers with the new hardware and to give them some supervised hands-on experience with both the equipment and its application in a series of experiential exercises included in a lesson plan outline prepared by the SME. Master teachers and participating teachers in attendance received a modest stipend to compensate them for their weekend time. A second hands-on workshop, on methods for isolation and identification of DNA, at the end of March 2012 (and two makeup sessions in mid-April to accommodate teachers' schedules) completed the formal presentations by Prof Lewis. Materials were provided to the teachers during the two sets of workshops.

A hardware item provided to the first year's participants was a simple kick net, which was used in an initiating group exercise among the participating teachers, who met on another weekend and waded out into a brackish habitat to collect specimens to populate their aquaria.

The device to evaluate the benefit—if any—of this intervention was to be a comparison of student scores on a standardized science test given at the end of grades 3, 5 and 8. In contrast to some earlier middle- and high-school studies, improvement in student performance rather than a direct test of assimilation of the content of the enrichment was to be the focus of the evaluation. Anonymized average scores for participating and matched nonparticipating classes at each of the schools were to be compared.

3.3.2. 2012–2013 School Year

The defection near the end of the school year of both the SME and the master teachers responsible for execution of the SY 2011–2012 program effectively prevented either a continuation of the first year's topics or the introduction of a new topic area to continue the active exercise. However, a cross-fertilization experiment described in Appendix C was conducted as a 6-week summer internship joining an elementary-school teacher, a rising Title 1 high-school senior, and a graduate student from a historically black university (HBCU) as a team to execute a "real" experimental task.

4. RESULTS AND DISCUSSION

4.1. 2011–2012 School Year

Of the 16 teachers who undertook participation for SY 2011–2012, only four were in place at the start of SY 2012–2013. The number of students still in place in the classrooms at the end of SY 2101–2102 was not recorded, and student turnover was not tracked, so the limited testing results (5th grade only), which suggested slight improvement, cannot be considered a reliable indicator of effect.

By the end of SY 2101–2102 the SME and all of the master teachers had, for a variety of reasons, left the project. A weakness of the initial design that quickly became clear was that the SME traveled from a remote location and so was not physically available to participating teachers on a day-to-day basis. However, the most disruptive single factor was an unworkable initial contracting strategy, which was pursued to a fairly advanced stage of implementation before the contracting office declared that it faced legal impediments that would have taken another year to remedy—frustration from the futile expenditure of enthusiastic planning energy had reached toxic levels by the time the grant was finally emplaced and the project started.

4.2. 2012–2013 School Year

Implementation of the contracting, logistical and management architecture was in place and a number of lessons to be learned were in evidence by the end of SY2101–2102. Contracting for year 2 was accomplished without event; however, the intensity of the effort to execute the technical component of the program displaced planning and the defection of the performing team late in the year removed elements that would have been necessary to deliver the originally intended planned content. A new master teacher was recruited and additional equipment and supplies were provided to the participating classrooms.

Two categories of data were to be collected at the beginning and end of this second year to measure effects carried forward from the first-year teacher preparation: performance by the next class taught by each of the participating teachers, and performance by students advancing from the participating classes. Interpretation of the data in the first category would provide a straightforward measure of retention and assimilation by the individual teachers, whereas their performance during SY 2013–2014 would be influenced by expected preparation in the second round of teacher preparation.

Evaluation of advancing student performance was to be somewhat simplified because the control group for comparison was to be classmates who did not come from participating classrooms, and anticipated initial test results were also to provide an additional measure of the previous year's effect. The comparison of scores by students advancing from one participating classroom to another was not expected to be able to sort the effects of retention by the teacher and by the students.

However, another series of lessons surfaced here. The terms of a grant typically do not include a requirement for interim reporting, so the loss of 75% of the participating teachers was not identified until SY 2102–2103 was underway and it had become clear that the body of participants was now too small to meaningfully continue the planned activities for the term. The important lesson that was so concealed until report preparation was begun is that some verification of clear understanding on the part of participants at all levels in the performing group of the specific aims of the exercise and how they are to be realized.

Standardized testing within BCSS also proved to be much less available than initial appearances had suggested. Future exercises of this sort will have to identify specific testing regimens and incorporate them into the initial design. Use of a contract rather than a grant offers regular feed-back in the form of interim reports—which provides opportunities for on-the-fly interventions—and appears a better mechanism to award funds for projects that include quantitative metrics; however, occasional onsite inspections appear to be advisable, particularly during early mid SY.

4.3. General Considerations

From the perspective of promoting equitability through social programs, Title 1 elementary and middle schools appear to be an obvious target for exercises in enrichment, STEM and otherwise; likewise, the teaching staff in these institutions might be expected to be the most responsive to such reinforcement and access to teaching tools, so the concept is attractive from two perspectives.

However, 1) unless and until such opportunities reach a majority of urban Title 1 classrooms, high rates of student turnover (i.e., only partial exposure) will limit the benefit to these students at more-advances grade levels; 2) as a laboratory for quantitative evaluation of the effect of enrichment, these schools are far less than ideal for several reasons—students are distracted by events and uncertainties in their lives and often switch schools in mid term, crises are a common occurrence, methods of teacher evaluation and reward appear to discriminate against Title 1 school staff and, not surprising, teacher turnover is fairly high. Performance data are therefore noisy and the *n* of test populations tends to fall off rapidly, limiting opportunity for long-term evaluation—the true test of effectiveness—of an exercise involving a workable number of subjects; 3) these students are clearly targets for attention but promotion of life and survival skills (including mathematics) may be of greater value to them.

The reason that STEM occupations are not more popular is simple economics. A spectrum of occupations—conspicuous examples include law (historically), finance and medical specialties—provide much greater and more immediate financial opportunities than science or even engineering careers and attract away much of the pool of domestic talent that might otherwise opt for STEM training. The hands-on experience provided by robot performance competitions in intermediate to advanced grades is an inspired effort to set the hook to draw students into engineering and related fields. However, as it is a long-term, spare-time exercise requiring volunteer engineering experience, such activities likewise benefit primarily the social classes that enjoy the availability of stability and both necessary resources.

Keeping that thought and returning to the present project, the true role of such an exercise has to be considered. If the single target is to increase the pool of talent entering STEM fields, the complications and inefficiencies plaguing Title 1 education severely depress the cost–benefit equation for that pool, so greater impact would be expected from making the investment in average, particularly small-town and rural classrooms. On the other hand, a moderately effective incorporation of science content in Title 1 classrooms should demystify science and technology to these students as adults, and might cut slightly into the influence of fundamentalist antiscience in the country—each a benefit fondly to be wished for but practically impossible to evaluate.

The SY 2011–2012 exercise provided a rich harvest of lessons about the pitfalls available to federal projects attempting to measure the influence of STEM content early in the educational experience, when attitudes about math and science are formed. SY 2012–2013 was a fallow season, allowing a window for recovery from the errors and disappointments of the first experiment, but not providing the anticipated opportunity to look for evidence of a persisting and possibly growing effect from assimilation and application of the SY 2011–2012 investments.

5. CONCLUSIONS

Both the design and the execution of this exercise included a number of serious faults that became evident as the exercise progressed. Candidate remedies to be tested during the next iteration of this project are listed below:

- Student and teacher turnover in urban Title 1 classrooms is large—enough in this case to drop the number of data points below the threshold for significance by the end of the first year. Some improvement may be realized in a vertically integrated k–12 system outside the city, and such an institution is being recruited for the next SY.
- One-on-one interaction with the teachers is known to be an important factor in enrichment exercises. The only occasional visits by a remotely located SME imposed a serious limitation on the amount of this type of exchange, and master teacher defections aggravated this deficit. The exercise for SY 2103–2104 has recruited a local entomologist on FSU-PC's faculty as the SME, and the original five local master teachers within the BCSS family will be replaced by a more-qualified resource person recently graduated from a doctoral program in education and employed by FSU-PC. How the gain in experimental skill will balance against the loss of proximity and available time is an element that will be evaluated.
- The award mechanism for SY 2103–2104 will be a contract, which will provide more-timely feedback on progress and, more importantly, on bumps encountered as the activity proceeds. Some minimally intrusive mechanism for onsite inspection of the process in action will be developed with staff of the participating school.
- The testing mechanisms used to evaluate effects on student performance of participation will be negotiated with the school staff to ensure that expectations are understood and realized. Likewise, the specific enrichment content will be negotiated with the school to better match the enhancement to the school's capabilities and resources.

After two years the concept of measuring the effect of enhancing STEM content in elementary-level classrooms continues to appear sound despite initial faults in the design, missteps during initiation and execution, attrition of the teacher cohort and emigration of students from the school district. The project was originally intended to continue to evaluate effectiveness through to a "true" endpoint by following the student cohort to the stage that college majors are declared; however, given the rate at which curricula evolve, the eventual information would be so dated that the burden of enlisting parents and developing devices to preserve participant anonymity would likely not be justifiable unless voluntary continuation through a friending or similar interaction in some social medium is implemented.

The practical benefit from intervention by providing experiential equipment to 16 teachers for enrichment of their classrooms is not diminished by the inability of this experimental design and team to capture a measure of its effect, and it will exert a lasting effect. The challenge for the next cycle is to acquire enough control of the experimental environment to extract interpretable quantitative information without suppressing teacher and (as a consequence) student growth.

6. RECOMMENDATIONS

The concept and general approach of measuring trends in student scores on interval performance tests still appear sound, whereas the implementation fell short of expectations in several aspects. If circumstances allow the project should be continued, ideally long enough to look for an effect on the number of students continuing their education through college and on the college majors selected by them—which bears directly on the goals of the STEM initiative. To do so would require individual agreements with parents to provide that information, which was not part of the activities to date, but social media sites suggest a possible mechanism for achieving such a long-term evaluation.

Strength of eventual conclusions from continuation of this study can and should be increased by conducting parallel such exercises in different areas of the country and pooling the results. A preliminary indication is that mathematical exercises involving observations from experiential science activities could beneficially be introduced into the preparation of elementary education teachers. Continued gathering of data will be necessary to verify that conclusion.

In the context of this project, addition of a member of the BCSS (and other school districts if the study is expanded) office who deals with standardized test scores to provide direct access to data and statistical evaluation of them is being strongly recommended. Likewise, engagement of a BCSS staff member trained in experimental educational projects would also increase the likelihood of a subsequent project's delivering an interpretable data set of student scores.

Appendix A: List of Equipment Provided to 2011–2012 Participating Classrooms

Digital microscope (Figure A-1) and associated firm/software
USB drive
Aquarium (Figure A-2), including pump and supplies
Kick net (to populate the aquarium)

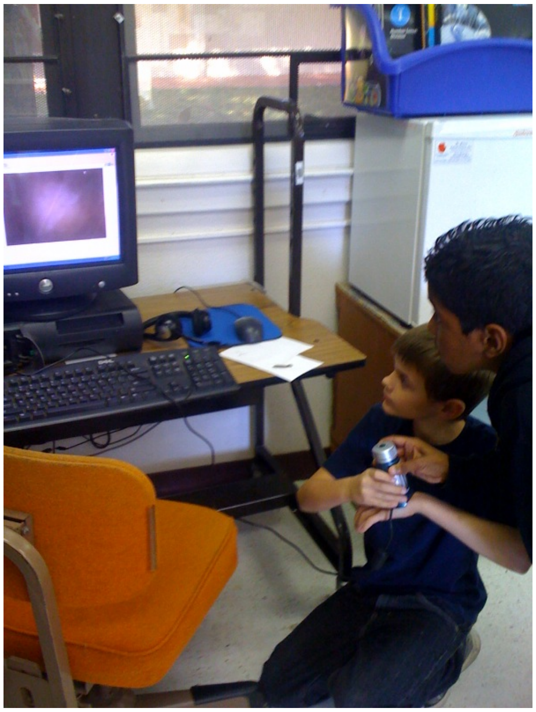
Figure A-1. Digital Microscope


Figure A-2. Aquarium

Appendix B: List of Equipment Provided to 2012–2013 Participating Classrooms

Triple-beam balance
Metric weight set
Refractor (to measure refractive index)
Commercial education kits: GEMS Color Analyzer and Optics (elementary)
Investigating Measurement and Density (middle)
Natural selection for AP Biology (high school master teachers))

Associated supplies were also provided, and supplies for 2011–2012 equipment were replaced.

Appendix C: Summer (2012) Team Internship Project

C.1. Concept and Environment

The vicissitudes during the process of initiating a contractual relationship with FSU-PC created a singular opportunity in which funding sufficient to support a summer internship project was at risk of expiring. This created an unplanned window to explore a concept of collective enrichment teaming students and teachers to perform a defined, common experimental task that could be completed in a window of six weeks. An experimental introduction and supervision were to be provided by an AFRL researcher in whose area of specialization and interest the task was defined. The team comprised a graduate student, a relatively young elementary education science teacher assigned to a Title 1 school and a rising high school senior, also a Title 1 student. The expectation was that the graduate student would develop communication skills by organizing the team's approach to the project; the teacher would acquire a hands-on perspective on the research process and a good understanding of the technical aspects of the project to provide a general feeling for biological science; and the rising senior would receive an introduction to scientific thinking and lab methods, and a sense of the role of science in the world.

C.2. The Lab Task

In recent years, biofuels have surfaced as a practicable partial solution to the global need for more-sustainable, "environmentally friendly" fuel sources. As one of the largest single consumers of liquid fuel and electricity, the US government is supporting research into biofuels as a possible means to decrease dependence on imported petroleum and non-renewable fossil fuels. A number of available sources of biomass from which power and fuel can be produced have been examined; one promising candidate, which enjoys the positive features of rapid growth rate, high energy content and ubiquitous growth potential, is algae. One paper reported that adding fine particles of cerium oxide (ceria) to an algal system 1) promotes growth, 2) confers ultraviolet protection on the cells and 3) improves the subsequent combustion process of the algae as a fuel additive. This suggested a compact project—design, conduct and analyze a series of experiments varying the amount and particle size of ceria particles added to achieve the fastest rate of accumulation of algal biomass and, ultimately, the largest energy yield available under those sets of conditions. As conceived this entailed growing, collecting, drying and weighing batches of algal cells, and burning them as a slurry in diesel fuel in a calorimeter to measure the energy yield.

C.3. Preparation for and Initiation of the Project

Laboratory space in AFRL/RXQ's energy laboratory at Tyndall AFB was set aside to house this project; the cognizant research engineer (who was completing a PhD program) gave an introductory presentation explaining the background for and scope of the project, and was available on call to answer questions for the six weeks of the project. The graduate student, who was studying energy yield from sweet potatoes as an MS project at an HBCU, was recommended by his preceptor, who had earlier worked in AFRL's labs. The teacher and high school student were recommended by FSU-PC's PI, who is also a long-time member of the board of the Bay County public school system. An Educational Partnership Agreement was in place between the school system and RXQ.

C.4. The Project

The team was given six weeks to complete the problem posed; all necessary tools, equipment and materials were available on site. Once assigned their task, the team was asked to prepare by performing literature searches to determine best practices to collect useful data and to familiarize themselves with the test protocols. This orientation process took much longer than expected and put the group behind schedule to complete their experiments. However, once the experiments began, they were able to collect useful data, learn from their experiments and mistakes along the way, and make more accurate measurements and draw conclusions as they went along.

As stated above, the team's task was to determine the best available concentration and size of ceria nanoparticles (nanoceria) to add to an algal suspension to promote growth. The team ran experiments to determine the concentration of algae by measuring algal growth with time in cultures in a common medium containing various concentrations of nanoceria. This entailed developing calibration curves that would 1) quantify the change in concentration of algae and, separately, the concentration of nanoceria. Both were measured using a UV–visible spectrophotometer. Figure C-1 shows algal concentration data generated by the team.

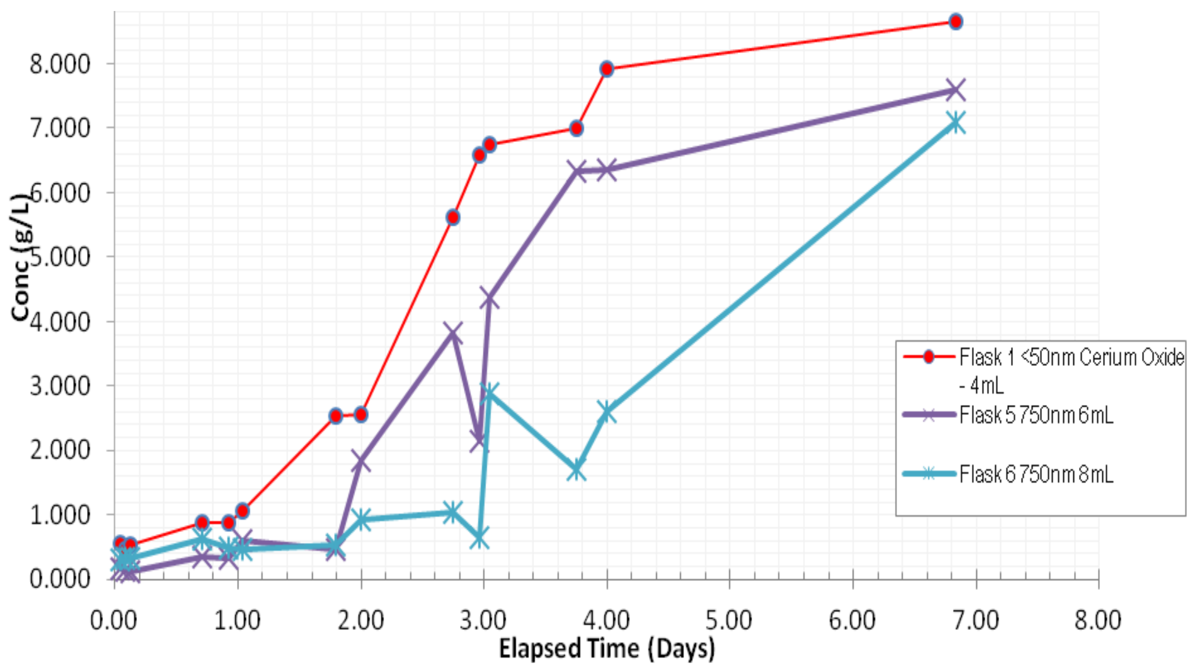

Figure C-1. Algal Growth after Addition of Varying Amounts of Ceria Nanoparticles

The team also used light and electron microscopy to visualize effects wrought on the algal cells by differing sizes and amounts of nanoceria. Figure C-2 and Figure C-3 are light and scanning electron micrographs taken by the team to illustrate cellular activity and cellular interaction with nanoceria.

At the end of the 6 weeks the growth experiments were incomplete and no combustion analyses had been started. A project review was conducted at the end of the period in which the three participants made a tag-team presentation of the project and attempted to answer questions from a small panel of BCSS and FSU-PC staff and AFRL personnel. No written materials were submitted.

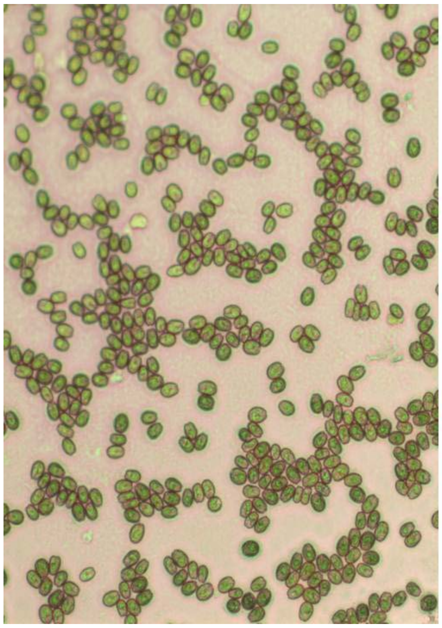

Figure C-2. Light Micrograph of Algae

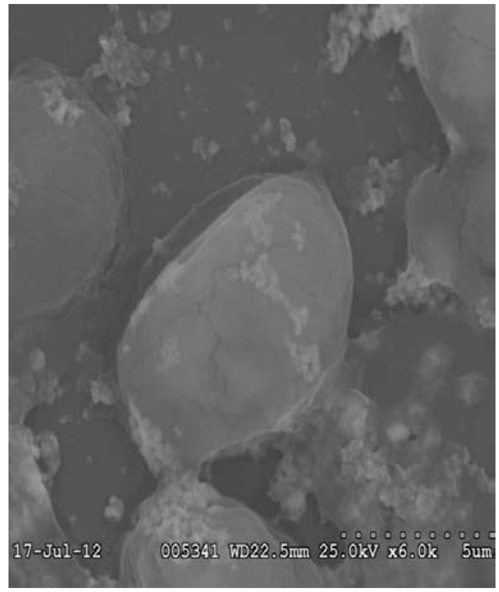

Figure C-3. Scanning Electron Micrograph of Algae and Nanoceria

C.5. Results

A postmortem interview with the teacher revealed that in the absence of effective guidance she had assumed control of the lab work and performed most of it herself and that the high-schooler had not engaged as deeply as had been hoped for.

A postmortem summary was also provided by the host engineer, who devised the lab task:

The team consisted of three diverse individuals with vast differences in scientific background and understanding, which posed some unique challenges. The concept for the structure was that the graduate student, who should have the greatest depth of understanding of the field, would lead the group, develop the problem, design the experiments, and guide execution of the plan by giving direction to the other team members and integrating results. The teacher, bringing a basic understanding of science and learning techniques, was to help execute the plan and work with the student to provide a mutual learning experience. This would include discovery of practical uses of science and engineering, and learning new concepts and the importance of education to teach young students. Finally, the high school student was to help perform basic experimental procedures and preparatory work while getting first-hand experience in a laboratory setting. The small-group environment was intended to draw each team member into close interaction with the other to promote both brainstorming and sharing of experiences and ideas.

In the lab, the team found it difficult to work together due to several factors. The largest problem facing the team—and apparent in each of the members—was minimal understanding of the scientific process. This created a problem organizing the experiments, executing the plan and handling data to interpret results and design next experiments to conduct. This degraded motivation to keep the team working together and moving forward as a group, and led to progressive decreases in group interaction and individuals independently pressing forward, leaving others behind “in the dust.”

The aim of this program was to allow people at various stages of development with various backgrounds to interact to achieve a common objective. In this case, the goal was only marginally met. A preliminary interview with the participants could have selected a better team and initial selection of a project better matched to the capabilities and levels of understanding. This could also be enhanced by earlier selection of the team members and more preparation time for background learning and interaction with each other and project leads.

C.6. Discussion

The three-person team was allowed to work at the Air Force Research Lab, Airbase Technologies Division (AFRL/RXQ) in the Deployed Energy Research facility for six weeks, with all of the materials and equipment that were needed to complete their designated task. The team was set to work independently establishing their own structure and responsibilities with minimal assistance from on-site staff. Initial guidance was provided by the host government engineer on the desired outcomes of the task, and contracted personnel provided minimal technical assistance and support of materials.

Through some combination of inadequate training and shyness the graduate student provided no leadership to the team (and, during interrogation at the outbrief, was unable to describe not only the project but also the technical details of his graduate project or its role in any context). In extreme contrast, the teacher dug right in and assumed command of both the team and the project, assigning specific tasks to the other two and providing the organization that drove the effort. The high-schooler engaged only part time in the project and was distracted by late-night socializing but, by the outbrief on the last day of the project, had acquired enough understanding and experience to describe accurately those parts of the project assigned to her by the teacher. The graduate student had not. Inefficiency of the team (which, in retrospect and as it evolved, should have been addressed by active intervention) slowed progress to an extent that roughly half the tasks of the project were accomplished. The dried algal masses prepared were preserved so combustion analyses could be performed later by the host engineer’s team—the data were of real value to his project.

C.7. Conclusions

The design of this exercise is sound and was based on a positive history of summer interns at RXQ. The weakness of the graduate student could have been detected with a preliminary screen; if an opportunity to repeat this exercise recurs this will be included as a lesson learned. The scope and character of the technical project were appropriate to both participant skill levels and the time allotted. The principal failings were in the execution of the exercise, and responsibility lies exclusively at the top. The host engineer was inexperienced and carried the idea of independence much too far—an approach of guided discovery would have been much more effective. A preorientation package introducing the broad area of the topic will also be supplied as read-ahead material for the first meeting. The PM delegated too much responsibility, was physically remote (11 miles) from the lab, and did not insist on regular progress reports. The most important ingredient missing was extensive individual interaction with technical professionals, which appears at all grade levels to be the single most-effective device to achieve effective enrichment at any level and in any context.

An opportunity was lost to raise the level of preparation and communication skills of the graduate student. The teacher was already a strong performer but wavering in enthusiasm in the hostile environment of public education in Florida; the experience of the summer appears both to have broadened her perspective into the scientific enterprise and bolstered her resolve to stay on the job—an unintended benefit to STEM education where it needs help the most. That the senior later changed her announced major from fashion design to coastal biology may be the single tangible product of the exercise, as the change may be a first step toward an eventual career in a harder science or medicine. It also suggests that similar exposure of students selected by science teachers to an effectively supervised, hands-on lab project might be an effective device to steer talent into STEM training.

As in the project in the Title 1 classrooms, it appears that most if not all of the operational missteps available and not related to safety were made in the course of this exercise. Assuming that the lessons learned are assimilated and addressed during the next iteration, there is every reason to expect that the concept will be applied with active but minimally intrusive supervision by experienced personnel with appropriate technical qualifications, and that the enrichments intended will be achieved.

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

AFB	Air Force Base
AFRL	Air Force Research Laboratory
BCSS	Bay County (Florida) public school system
EPA	Educational Partnership Agreement
FSU-PC	Florida State University, Panama City campus
PLTW	Project Lead the Way
PM	program manager
RXQ	Airbase Technologies Division
SME	subject matter expert
STEM	Science, Engineering, Technology and Mathematics
SY	school year